Tevatron Beyond FY03: Status, Issues and Plans

Vladimir Shiltsev

Fermilab BD/Tevatron

Content:

- Introduction: beam parameters now and then
- Issues:
  - Beam-beam issues/compensation
  - Impedance/instabilities control
  - Injection
  - Control of orbit, tunes, coupling, chroma's
  - Luminosity leveling
  - Recycling
- New hardware/diagnostics
- Beam studies

Introduction: Beam Parameters in Run IIU

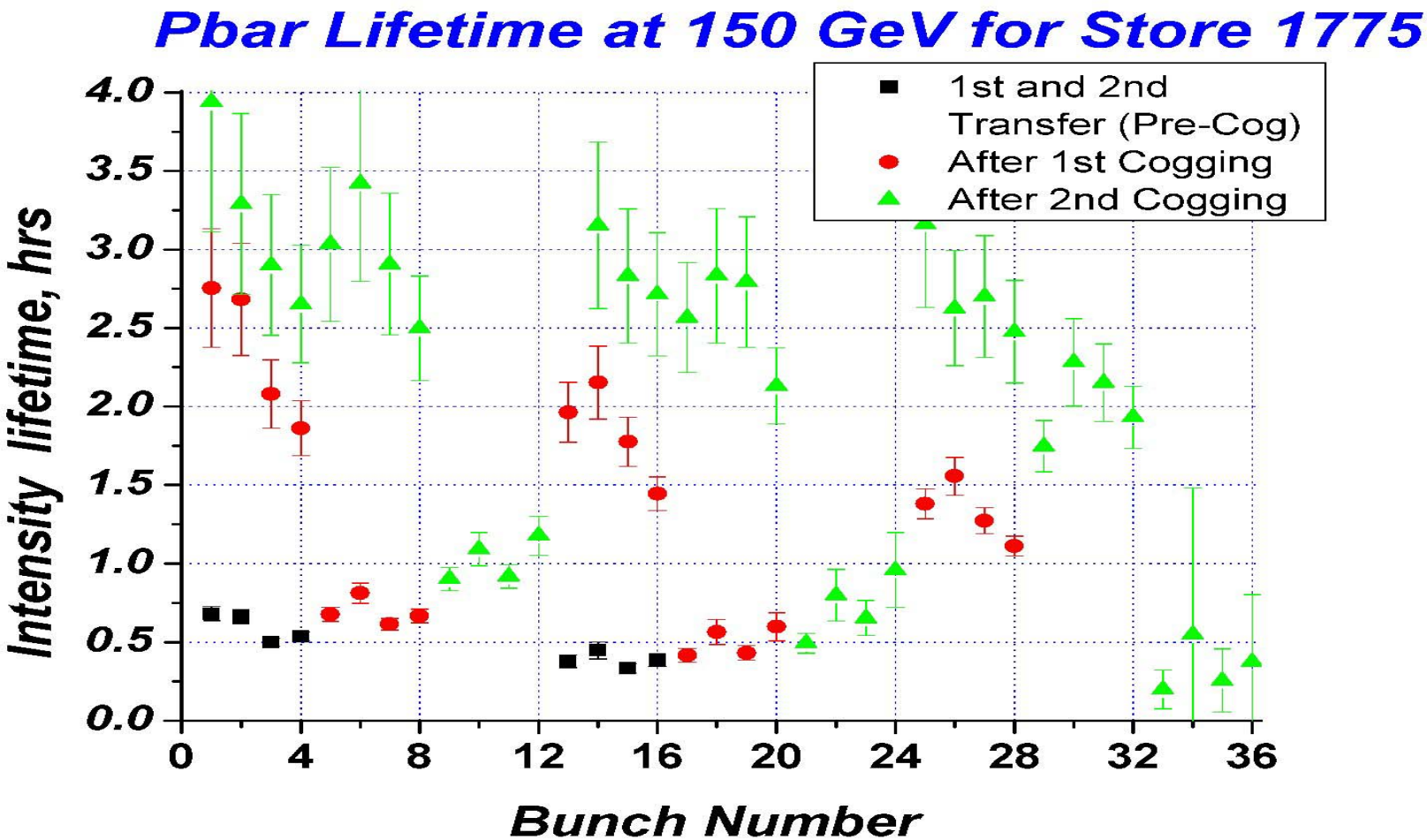
- differences between now and then: *L gain*
  - more protons x 1.5
  - more pbars x 5.4 (to ½ of p's)
  - shorter bunches x 1.05
  - ~ same transverse emittances

  total: x 8.9
- as the result:
  - Stronger beam-beam on pbars
  - Beam-beam on protons
  - Coherent beam-beam interaction
  - Stronger instabilities … in both beams
  - Tighter tolerances on transfers: intensity and emittances
  - Tighter control of tunes, orbit, coupling, chromaticities

Beam-Beam Effects Now: Summary

- see details in M.Martens and V.Lebedev talks
- p's on pbars:
  - reduced lifetime at 150
  - losses on ramp, in squeeze
  - bunch-by-bunch variations of tunes and emittances
  - tunes and chromaticities matter
- pbars on protons:
  - Losses while cogging, squeeze
  - bunch-by-bunch variations of tunes and emittances
- ongoing work to perfect models, codes

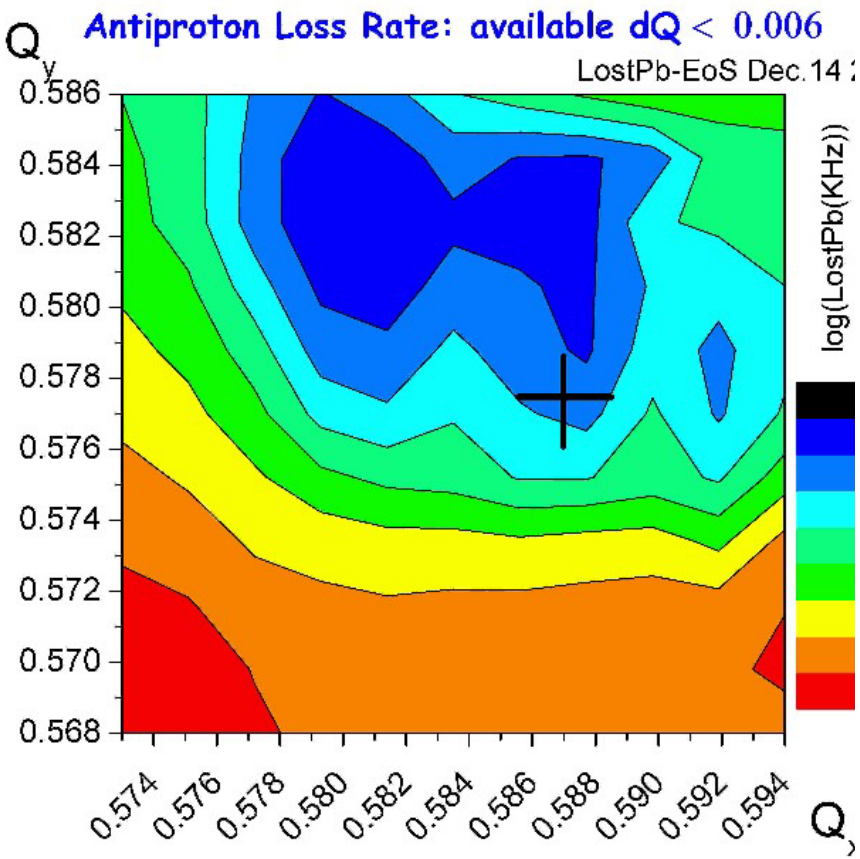
Beam-Beam Effects Now: Injection

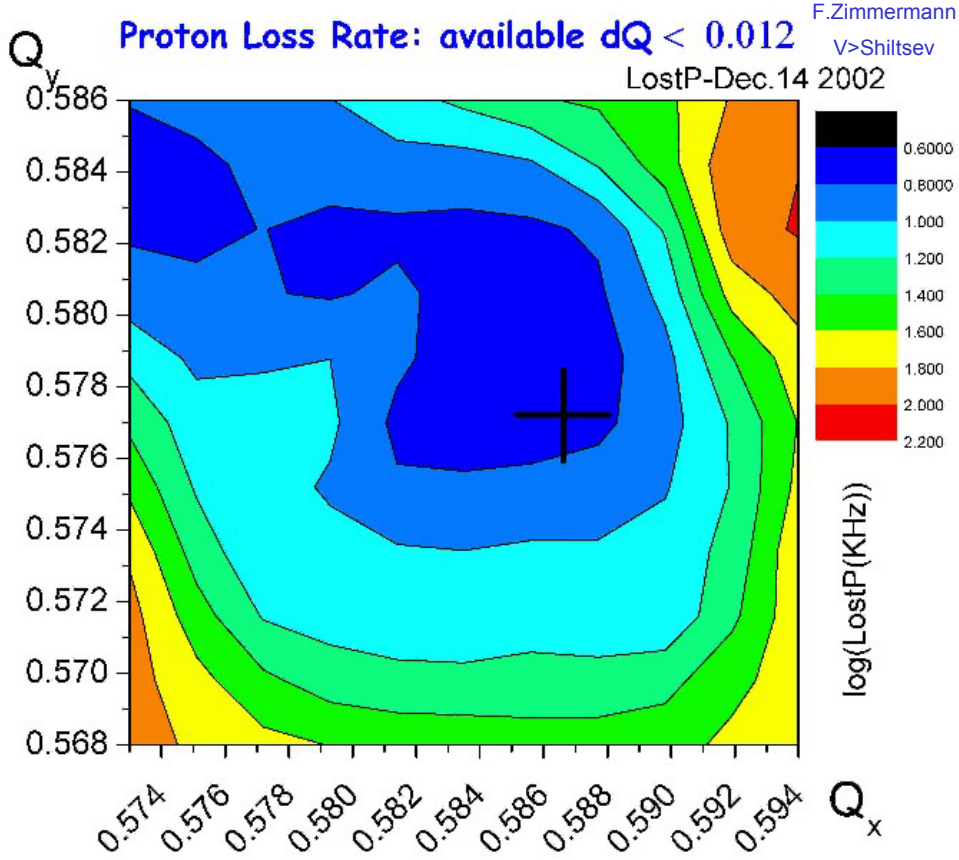


- Loss depends on N_p, separation, aperture, emittances, dp/p, tunes and C_v,h
- Scaling not determined yet – to be done ASAP

Beam-Beam Effects Now: HEP

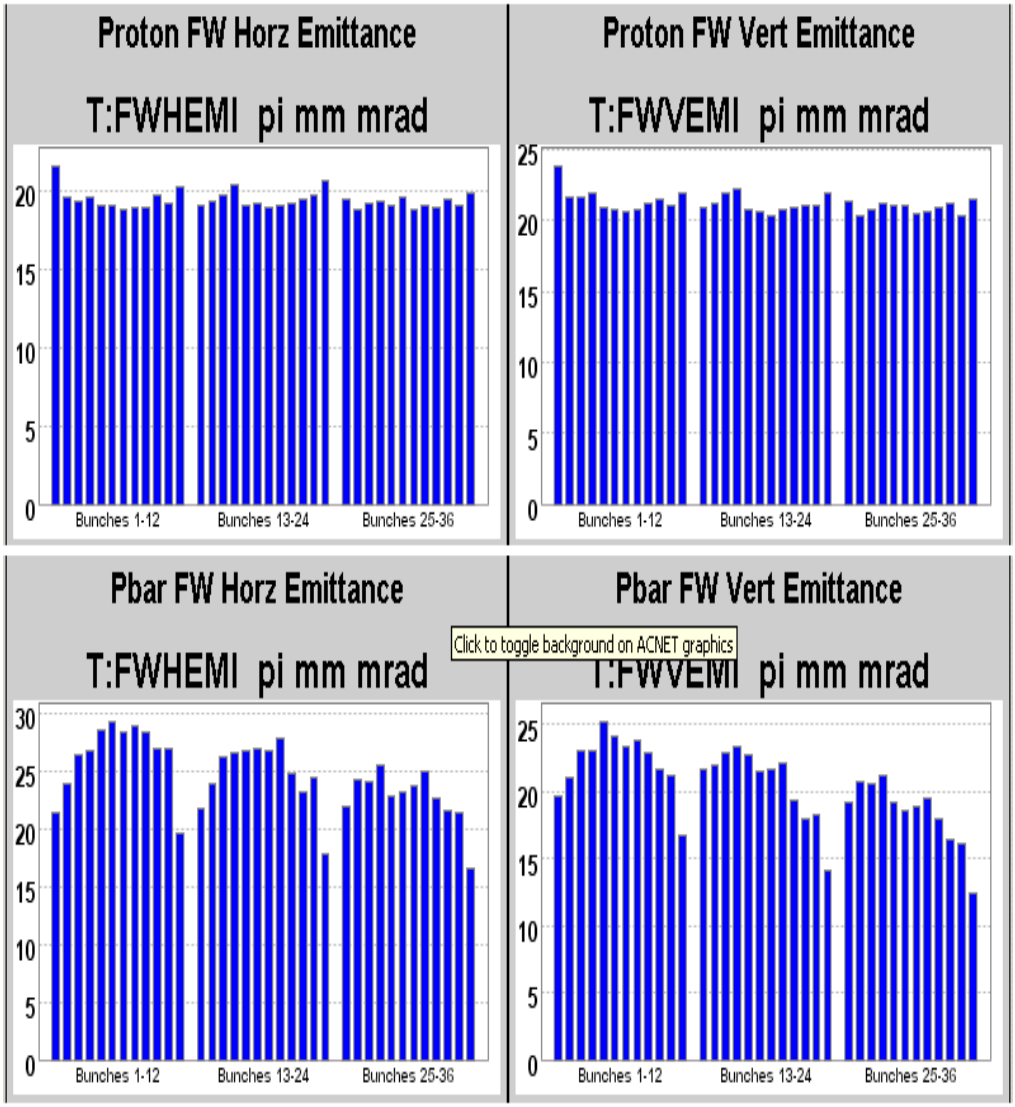
XL.Zhang, M.Xiao
K.Bishoberger,
F.Zimmermann
V>Shiltsev





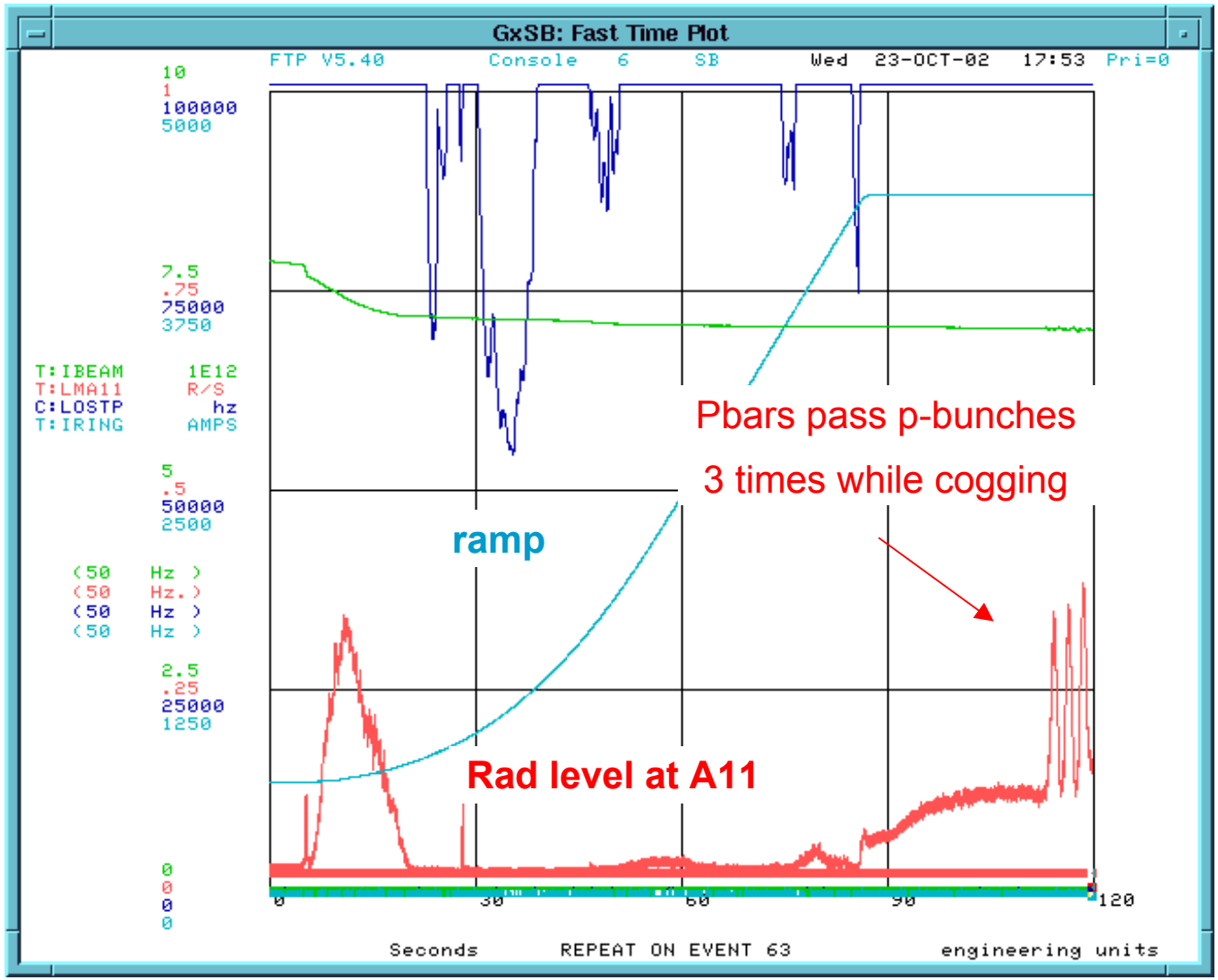
- At the beginning of the store available WP area is even smaller dQ < 0.004 … and this is at N_p=180e9
- No available tune WP space expected above 240e9

Beam-Beam: Bunch-by-Bunch

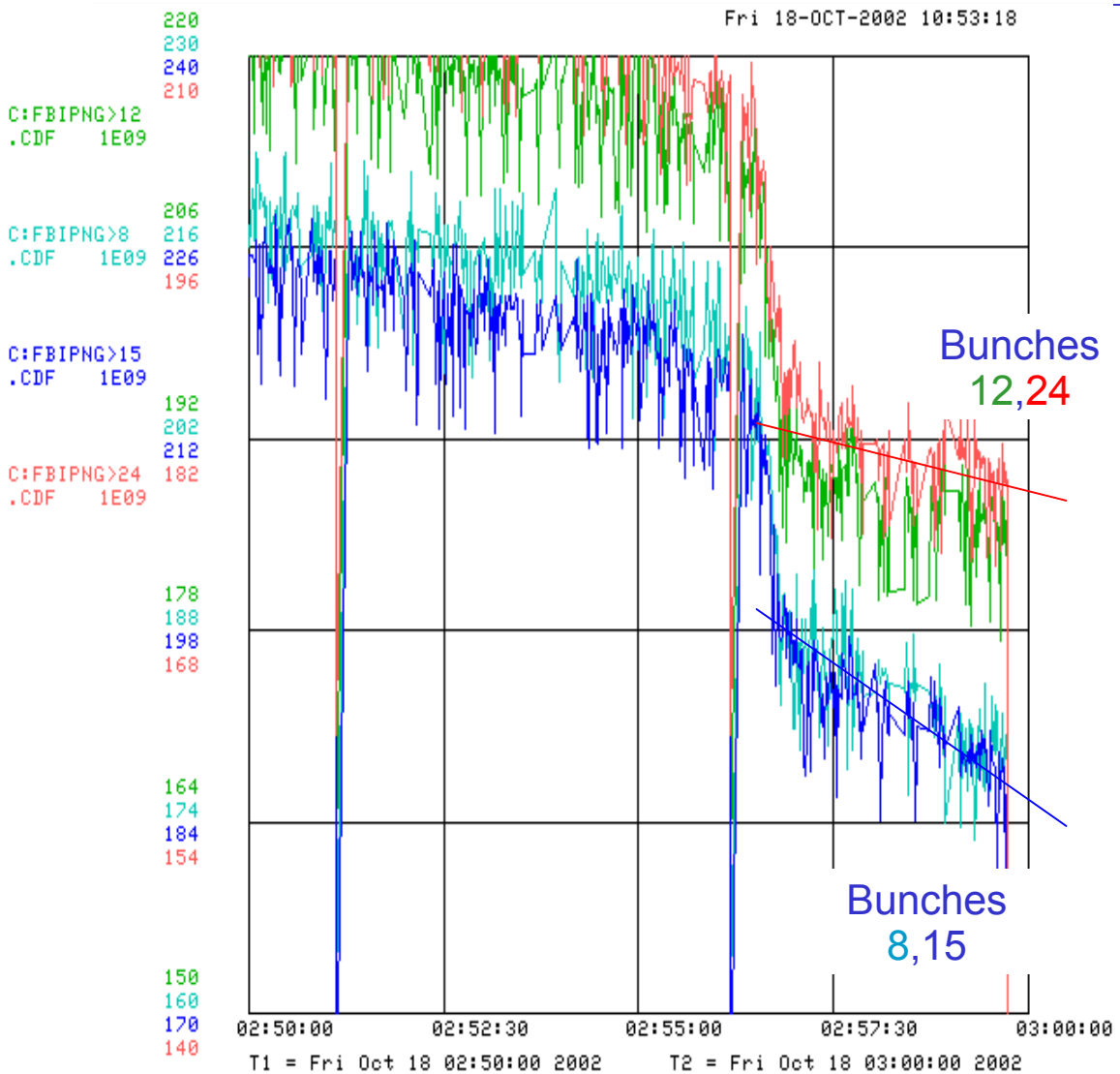


- "Scallop" profile of bunch emittances
- At the beginning of the store

Proton Losses While Cogging Pbars



Beam-Beam Effects in Protons



See losses in squeeze in store #1868

- Losses of bunches #12,24,36 were small (1e9/min)
- All other bunches lost intensity very fast (4e9/min)
- That resulted in quench at A11

We have small "anti-scallop" ("smile") effect in proton emittances at HEP

- Bunches #1,12,13,24,25,36 have 1-2 pi larger emittances than others after being 1-few hours in collisions
- Their intensity lifetime is smaller, too

Antiprotons also help to make protonbeam more stable on ramp and squeese

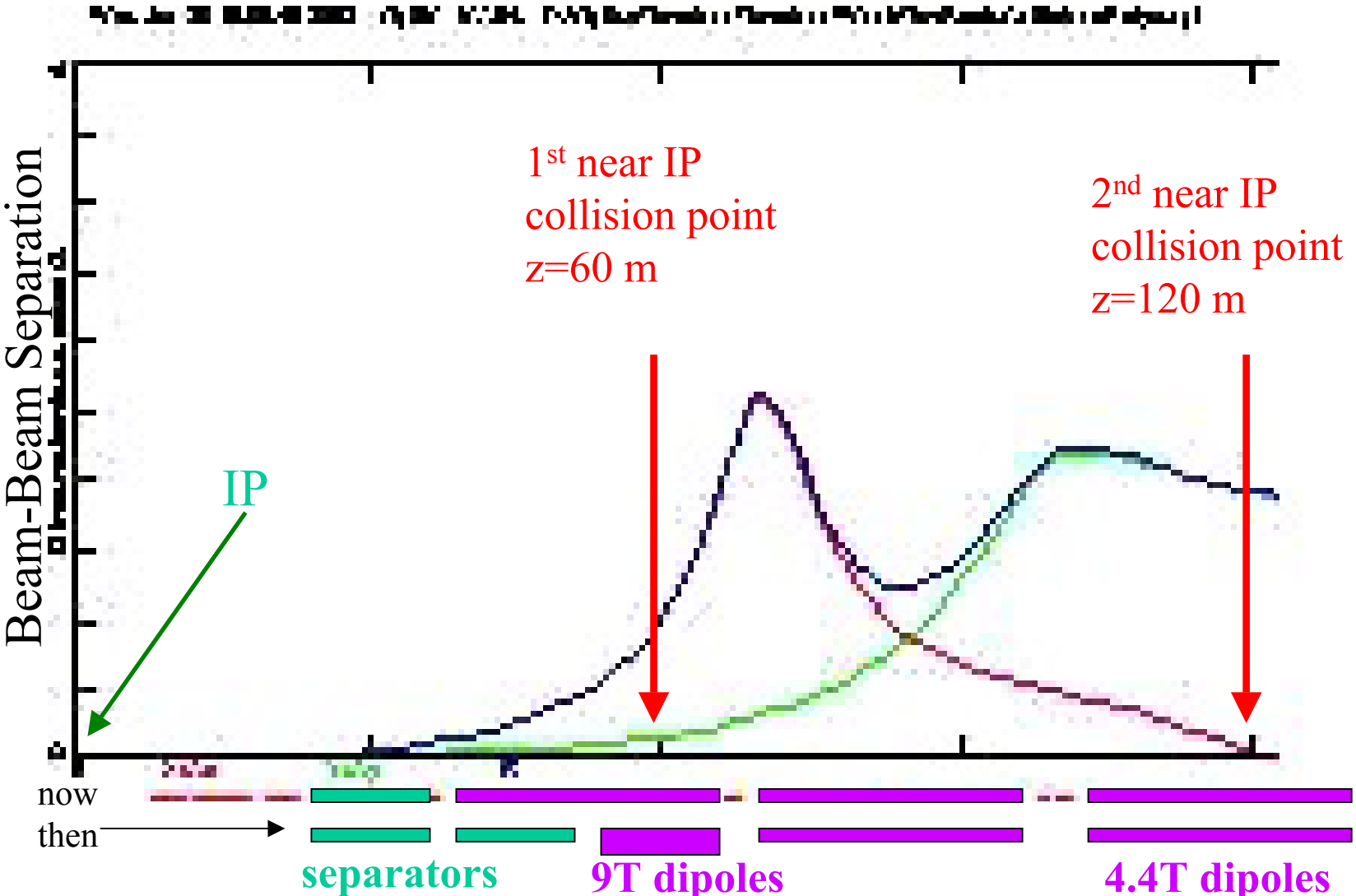
- Proton instability is rarely observed in 36x36 stores compared to the same intensity 36x0 stores
- Tune spread due to pbars is about (few)e-4

How to Deal with Beam-Beam?

- Larger Beam-Beam Separation

  (open aperture, optics, add separators)
- Add 6 proton bunches → 42x36 scenario
- Beam-Beam Compensation (TELs)
- Wire Compensation

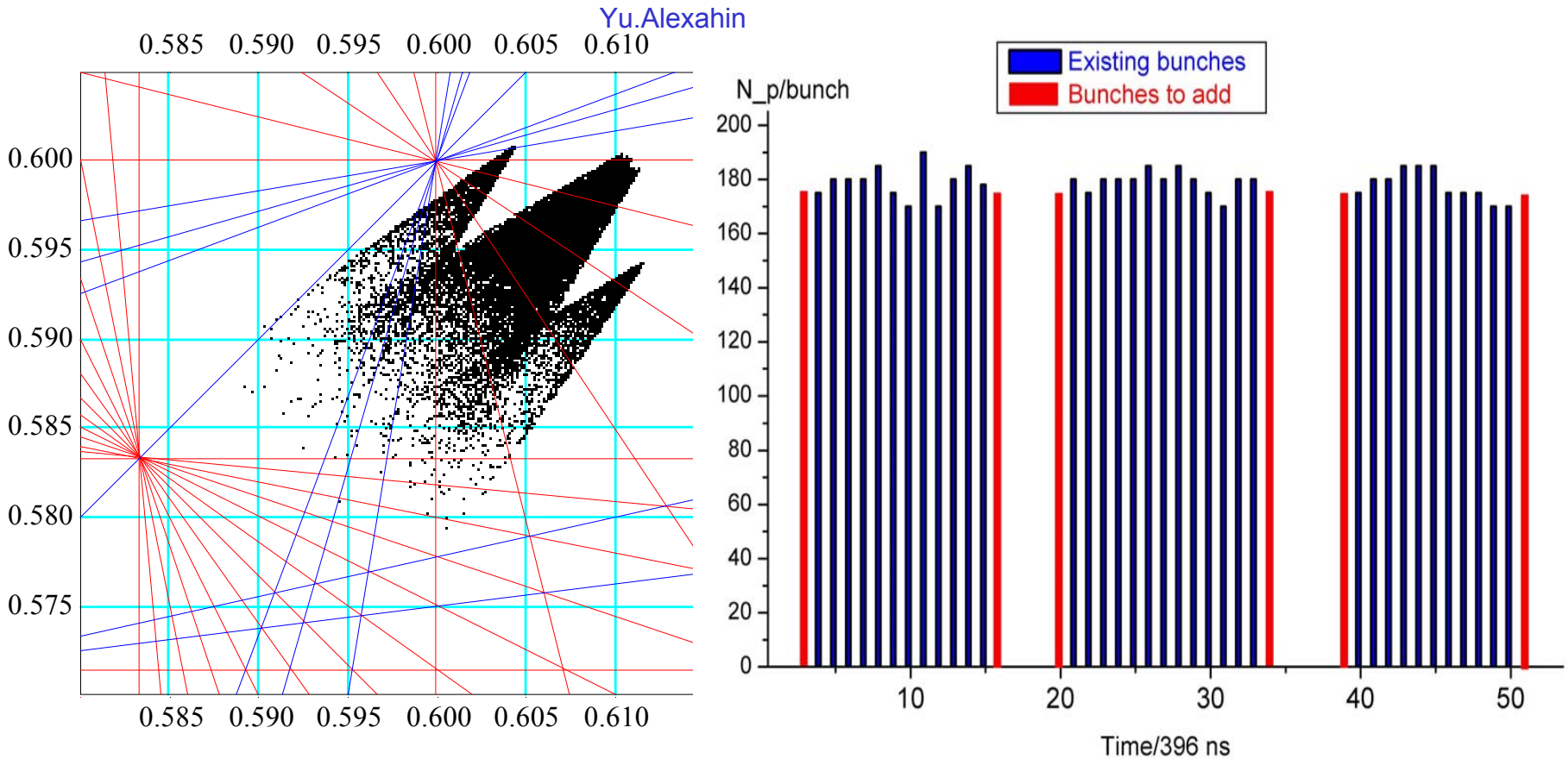
More Separators → 6-9T Dipoles



Comments on "more separators"

- Larger Beam-Beam Separation
  - Add separators → need space → shorter 6-9 T dipoles
  - Will double beam-beam separation at 980 GeV , so, long-range will not be a problem
  - Will not reduce head-on beam-beam interaction
  - Will not help much at 150 GeV (aperture limited)
- To get it in 2006 → start 6-9T design now
- 6T TeV compatible dipole built, IHEP-96/75
- Plan: involve TD and get estimates

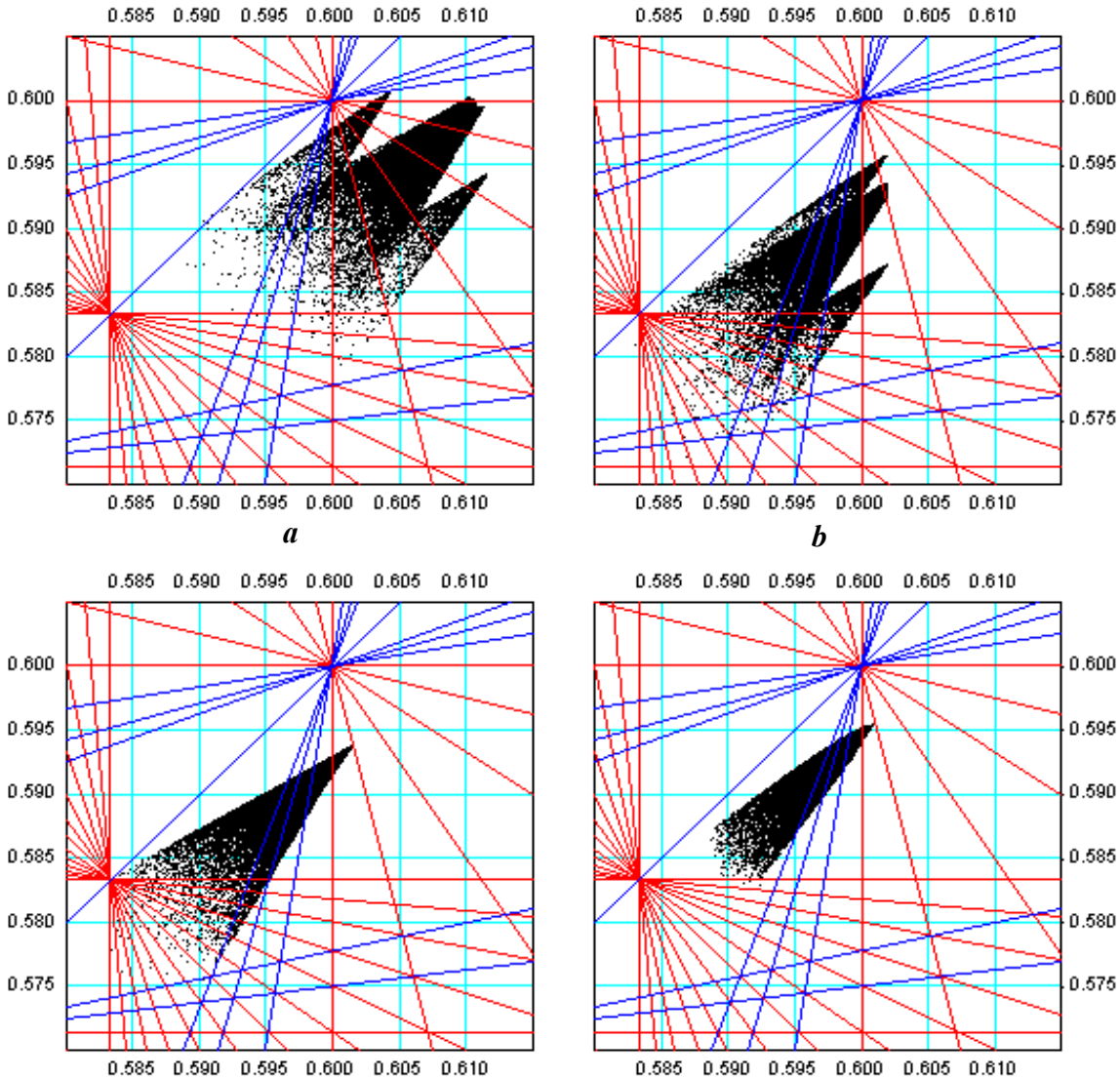
Add 6 Proton Bunches



- Will help at HEP only – reduce pbar bunch tune spread
- Will make beam-beam worse at 150 GeV, ramp, squeeze; faster kicker
- Plan: consider details and, perhaps, perform beam studies

Beam-Beam Compensation

Yu.Alexahin

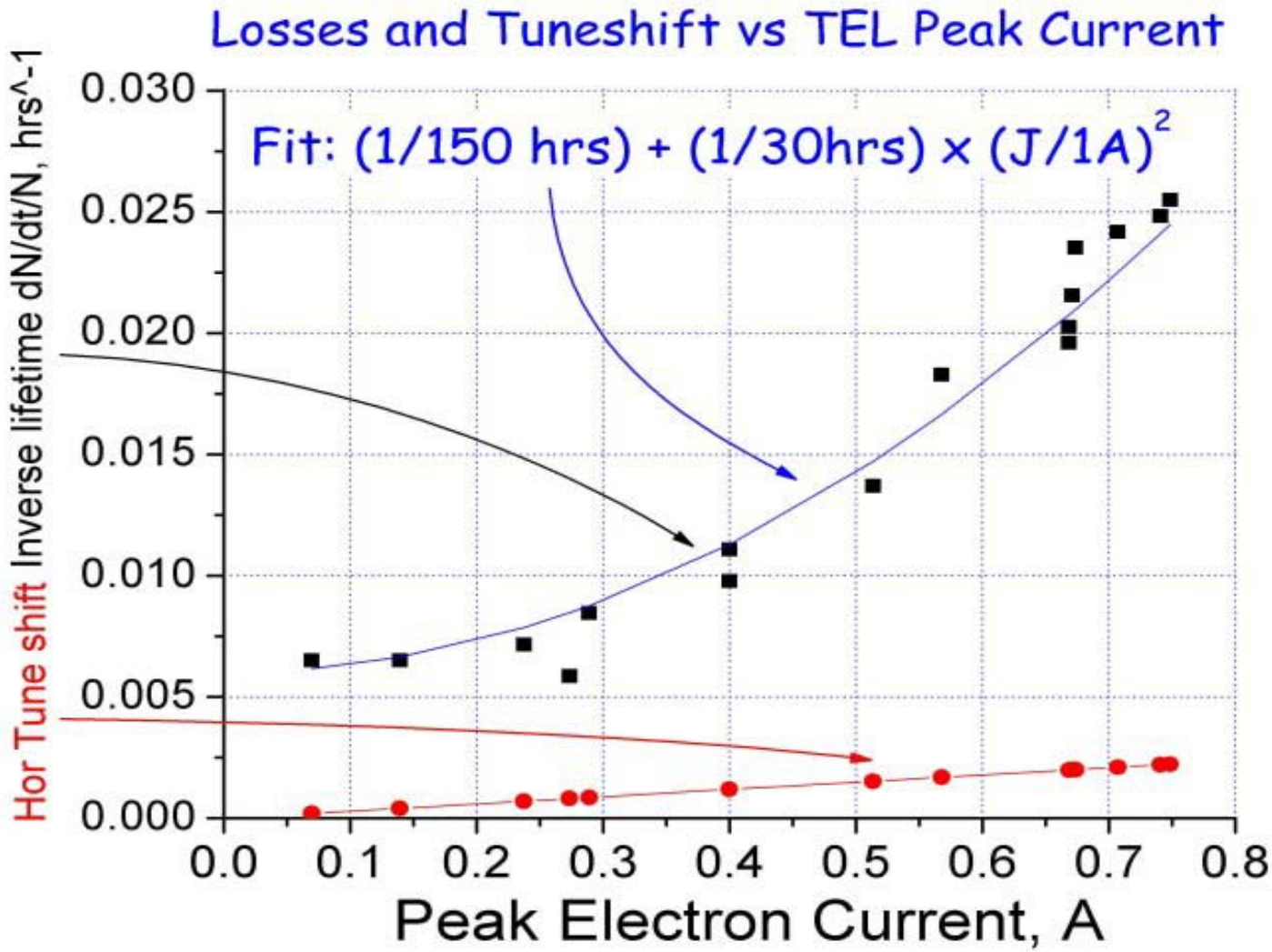


- compensate beam-beam tune shifts
  - a) Run II Goal
  - b) one TEL
  - c) two TELs
  - d) 2 nonlinear TELs
- requires
  - electron current √
  - stability ?
  - centering ⊗
  - shaping ⊗
- other considerations
  - use at 150 GeV, ramp, squeeze ?
  - chromaticity ?
  - abort gap cleaning

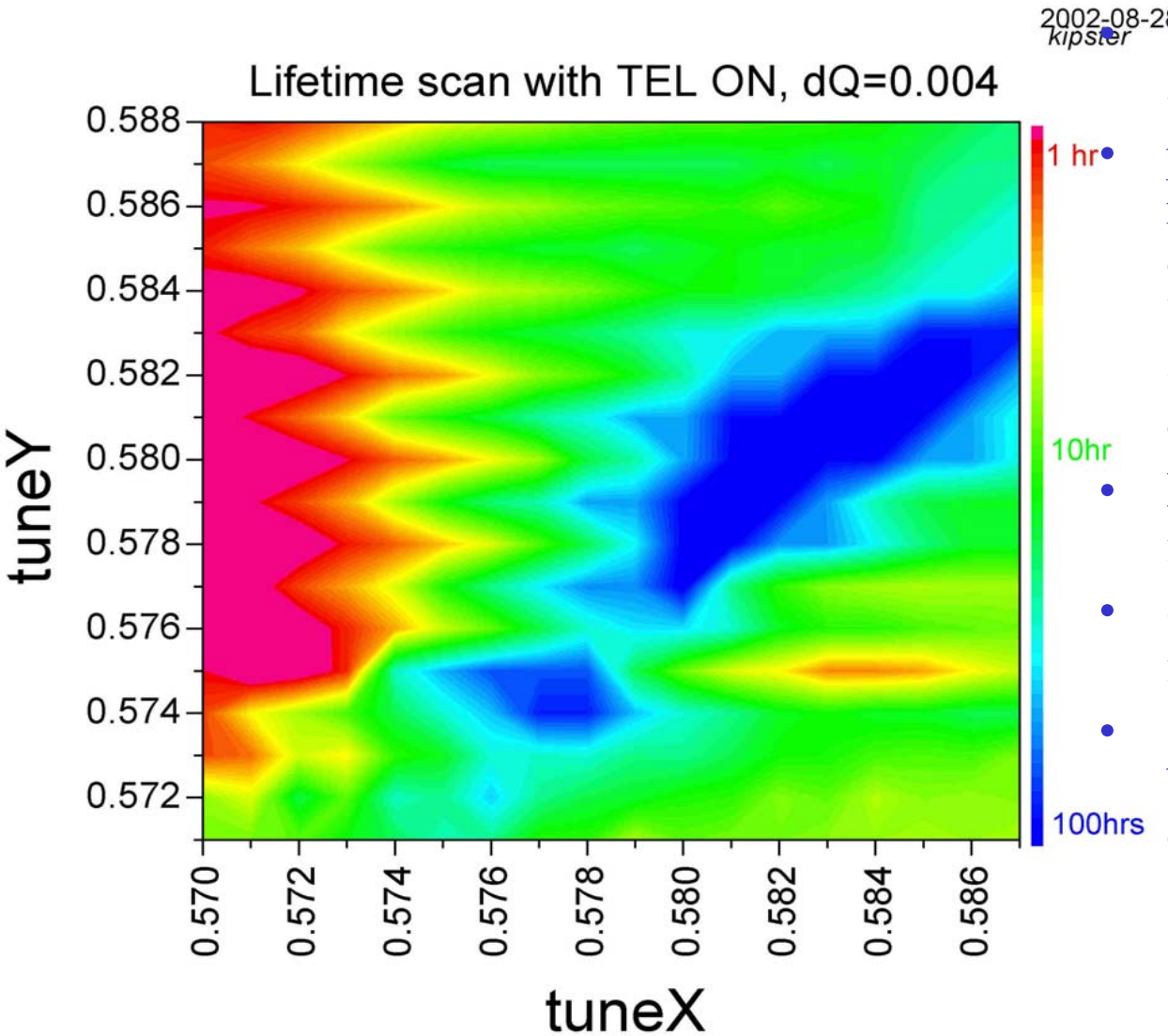
Comments on B-B Compensation

- Status:
  - dQ~0.009 tuneshift achieved
  - the best p-beam lifetime of ~100hrs achieved
  - lifetime strongly dependent on tunes = N-L B-B
- Plan:
  - need wider or Gaussian e-beam, center better
  - better beam current and position stabilization
  - new HV modulator
  - spares
  - TEL-2

Beam-Beam Compensation - I

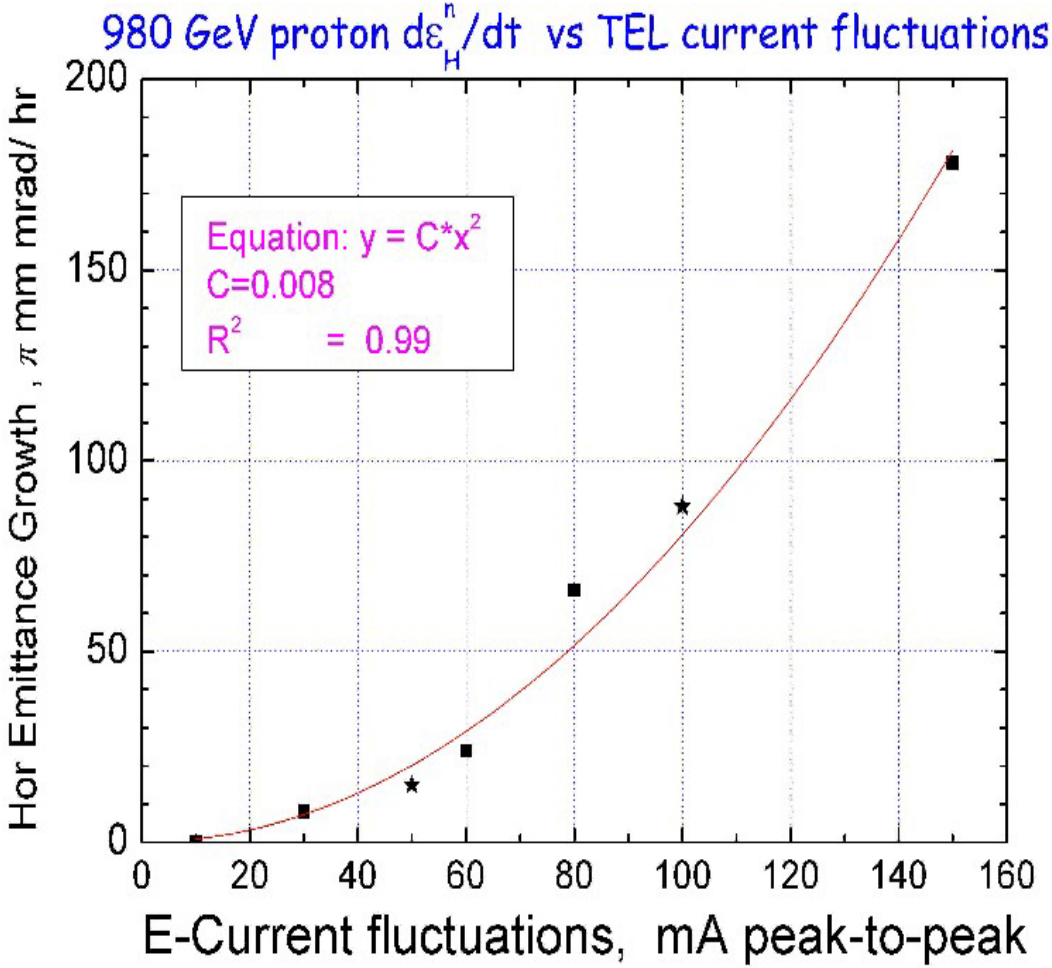


Beam-Beam Compensation - II



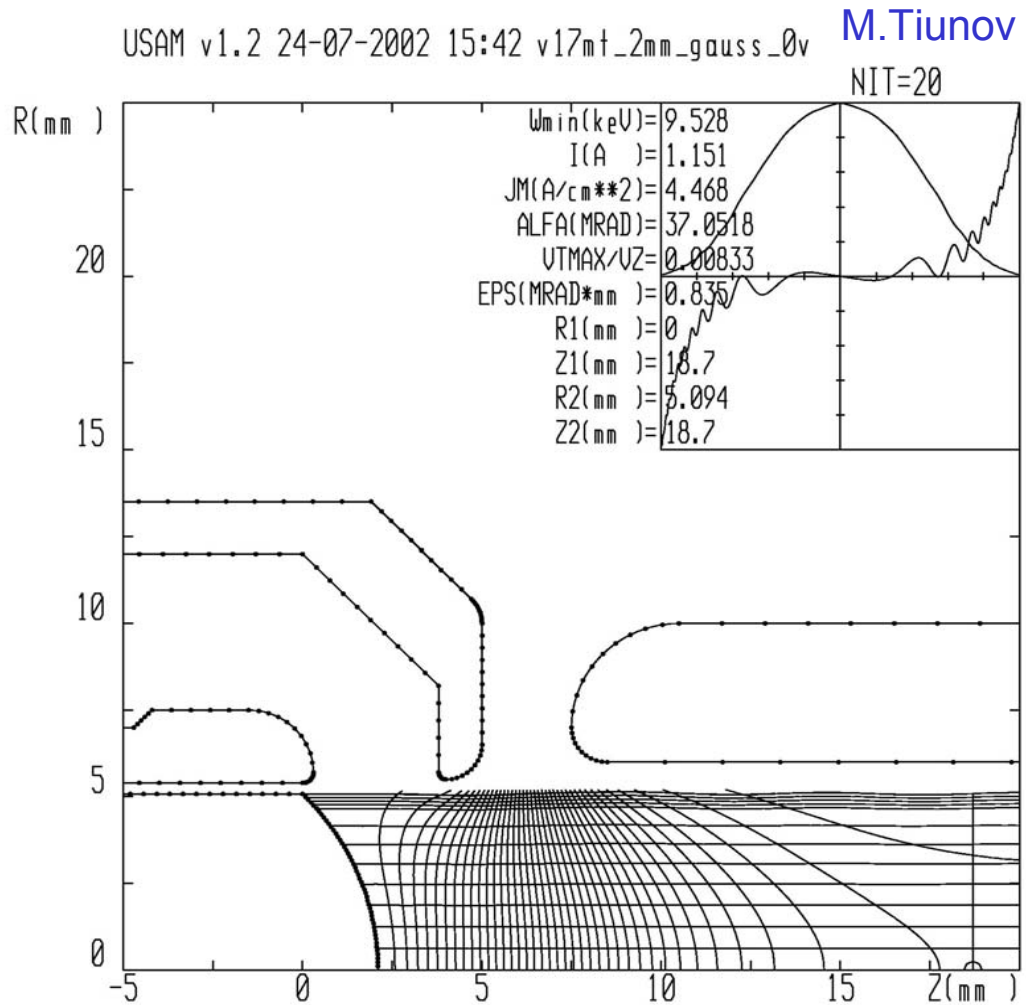
- TEL e-current noises are small
- p(pbar) lifetime reduction due to TEL comes from non-linear beam-beam effects - "donut collimator"
- Lifetime at good WPs is about 100 hrs
- e-beam positioning is important
- Smoother edge e-beam is needed → Gaussian gun

Beam-Beam Compensation - III



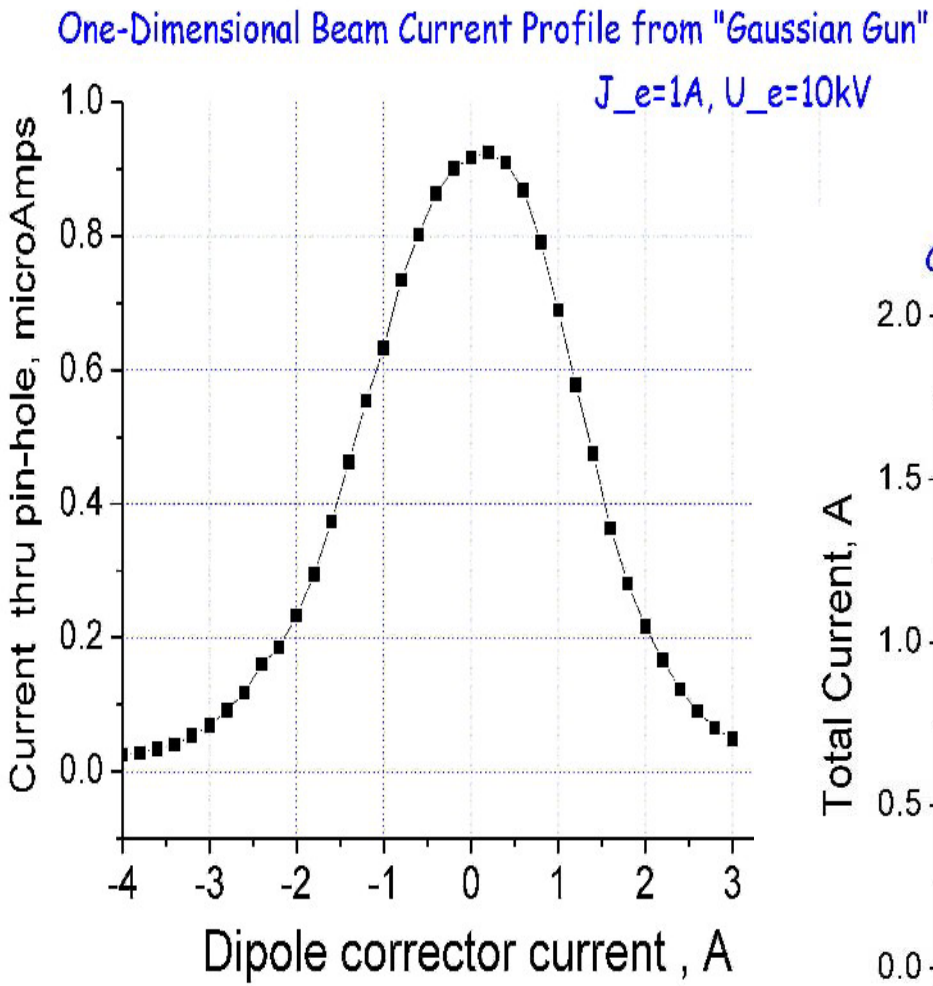
- TEL e-current turn-by-turn noise amplitude while operating for BBC with dQ > 0.005 dJ_e ~3-5mA p-p
- → 0.1-0.2 p/hr
- That is comparable with "natural" emittance growth of 0.2-0.5 p/hr
- → we plan to consider possibilitie for dJ_e and dX_e stabilization

Gaussian Gun for TEL

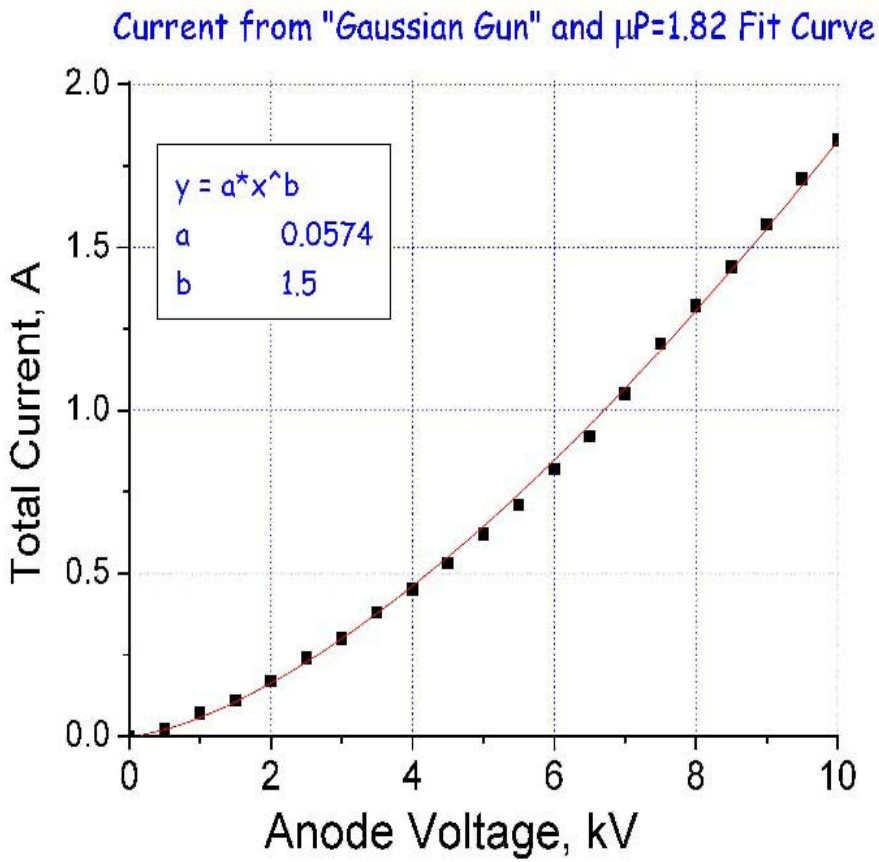


- Profile controlled by special electrode
- Somewhat reduced current density in the center → need of higher voltage
- Installed Jan

Gaussian Gun for TEL – II



G.Kuznetsov,
K.Bishofberger
N.Solyak



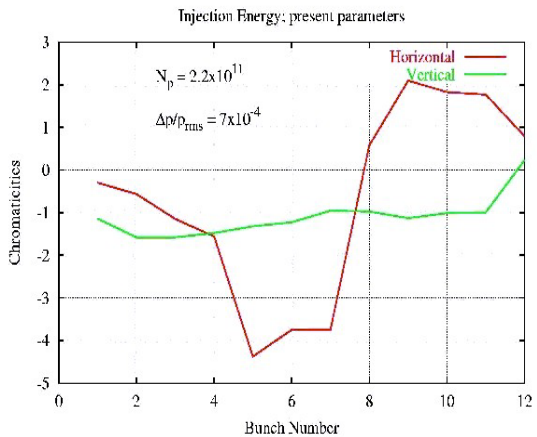
Comments on Wire Compensation

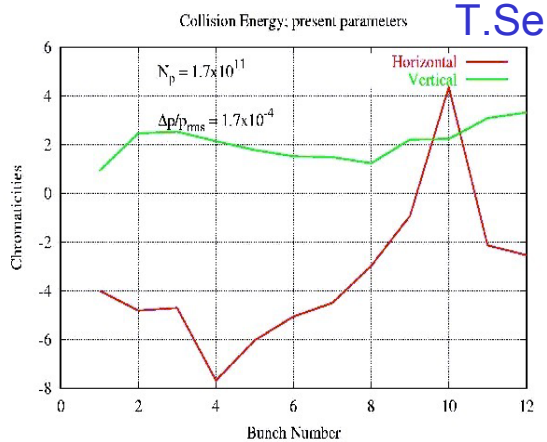
- "One wire per parasitic IP" – only few can be installed
- Few(4?) wires can handle near IP crossings if installed at proper locations (near IP)
- That will leave unaddressed beam-beam issues at 150, ramp and squeeze and will not fix "head-on"
- Pulsed wires - tough vs DC
- Plan:
  - Consider gain (simulations) and technical details
  - Closely watch progress with wires at CERN

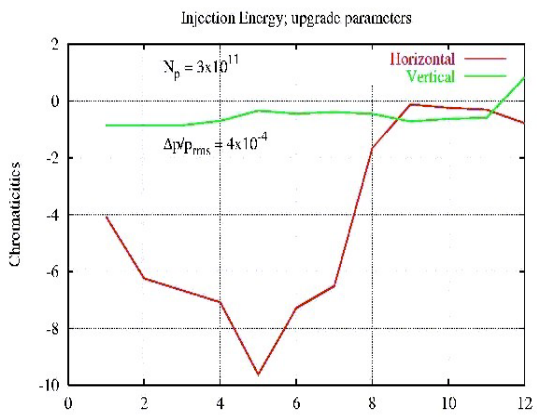
Comments on Beam-Beam Issues

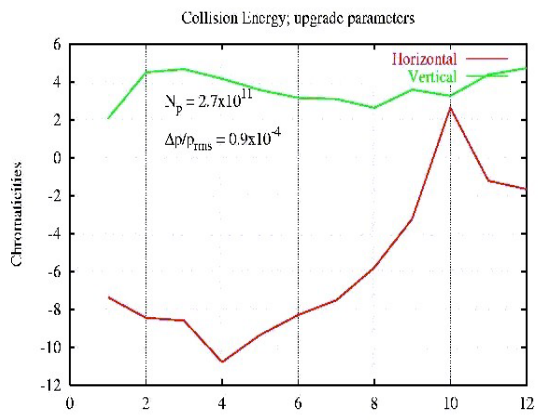
Small amplitude beam-beam chromaticities

T.Sen



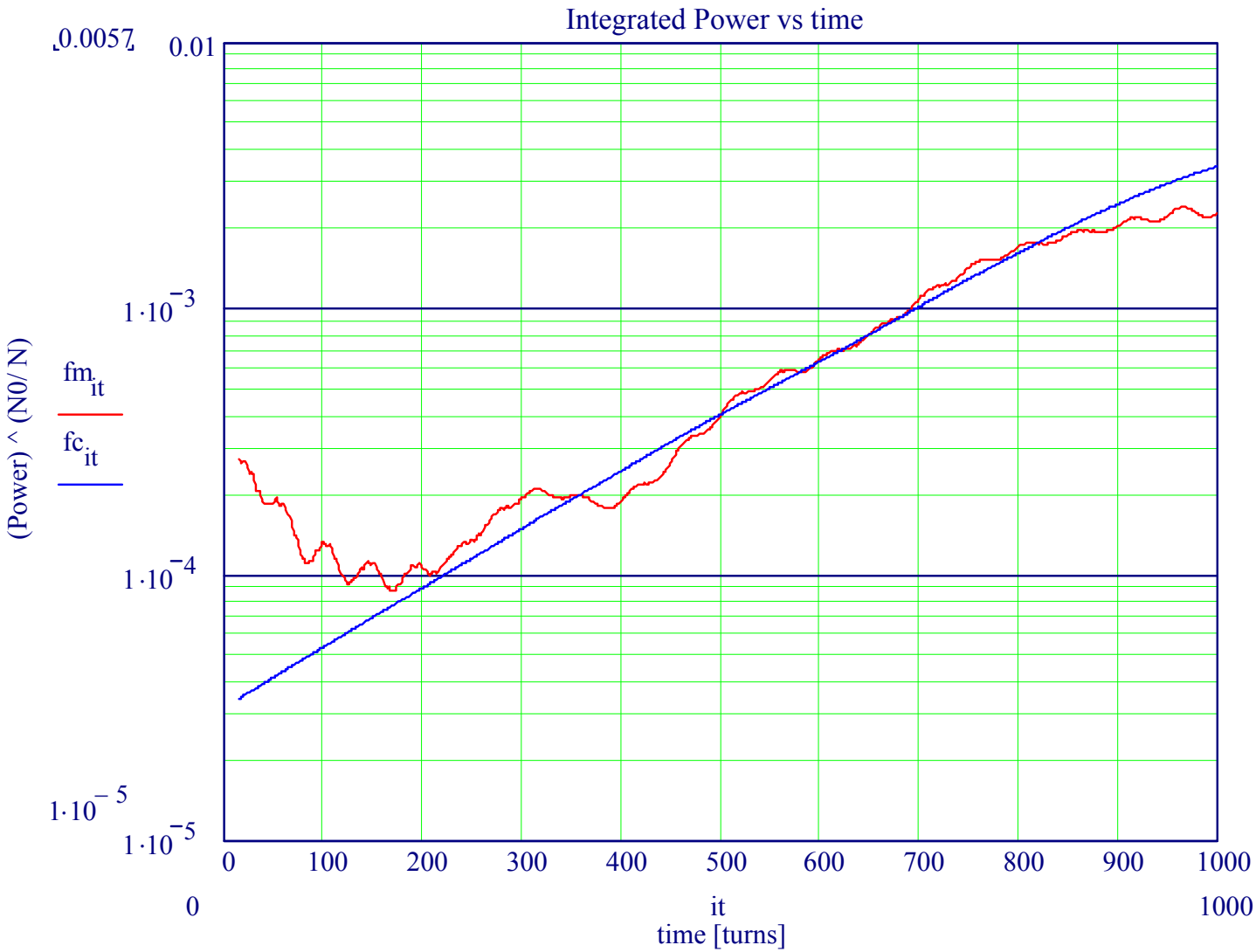






- So far numerical tracking can not explain beam lifetime, DA simulations qualitatively agree with observations but do not have quantitative predictive power
- Phenomenological models are simple ("soft collimator", Valery's model) and not backed up by theory
- We are aware of parameters important for beam-beam other than N_p, tunes, emittances : chromaticities, coupling

Control of Beam Instabilities



P.Ivanov,

A.Burov,

V.Scarpine

150GeV, 270e9/bunch

Chromaticity = -2.6

1/t = 130 ±15 1/sec

or 370 turns

Comments on Beam Instabilities

- Status (see also Mike Martens talk):
  - Transverse “weak head-tail instability” identified
  - Dampers “semi - helpful”: only at 150 GeV, still +C_v,h
- In Run IIU
  - damping time should be 50% faster (i.e., 300 turns→200)
  - need dampers for both proton and pbar beams
  - damper modification for better control of higher modes
  - remove sources of impedance where possible
- Plan:
  - Learn more from current experience

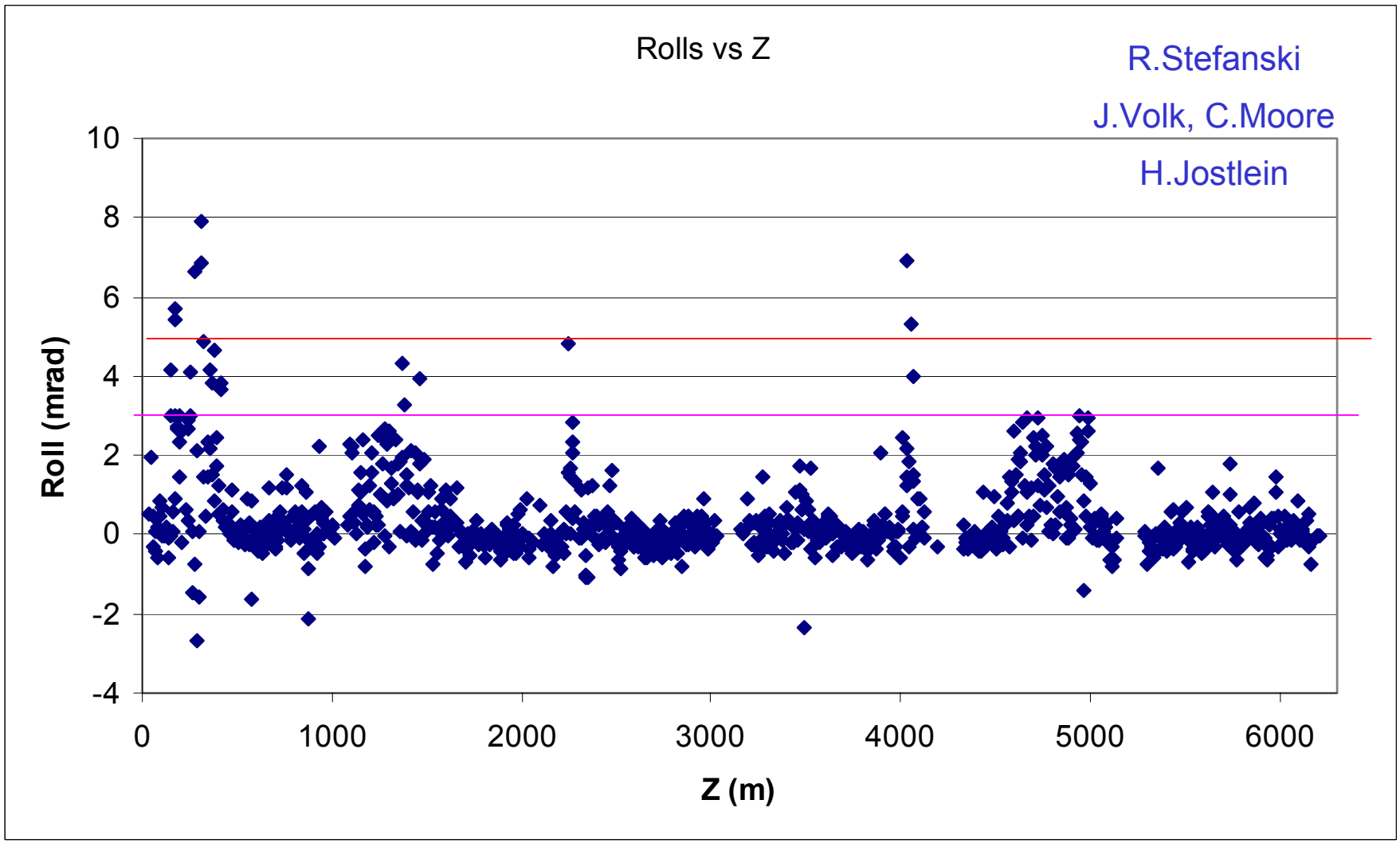
Injection Issues

- Status:
  - BLT operational (<0.5 mm error)
  - A1→ Tev emittance mismatch not fixed
  - Injection dampers are coming soon
  - Strange blowup on ramp
- In Run IIU
  - challenge is to deliver much higher intensity beams with the same or smaller emittances
  - smaller transfer losses require smaller emittances at injection
  - does not seem that there is much that can be done in the Tev if injection dampers work and A1/Tev mismatch fixed
- Plan:
  - Learn more from current experience
  - Study noise effects

Control of Machine Parameters

- Status:
  - Control of orbit, tunes, chromaticity, coupling quite an issue now (see M.Martens talk)
- In Run IIU
  - Need fast on-line diagnostics of tunes, chromaticity and coupling; p/pbars; bunch-by-bunch - NOW
  - Need of on-line data on magnetic fields in the Tevatron magnets – *in situ* or reference dipole(s), quad(s)
  - On-line measurements of magnet rolls, quad positions
  - faster alignment, fix stands
- Plan:
  - Involve TD, CD, other labs

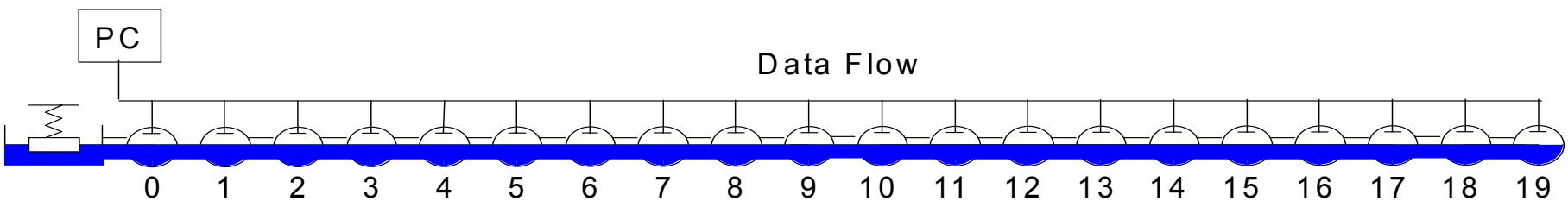
Tevatron Magnet Rolls



Tev On-Line Survey System: Elevations and Rolls

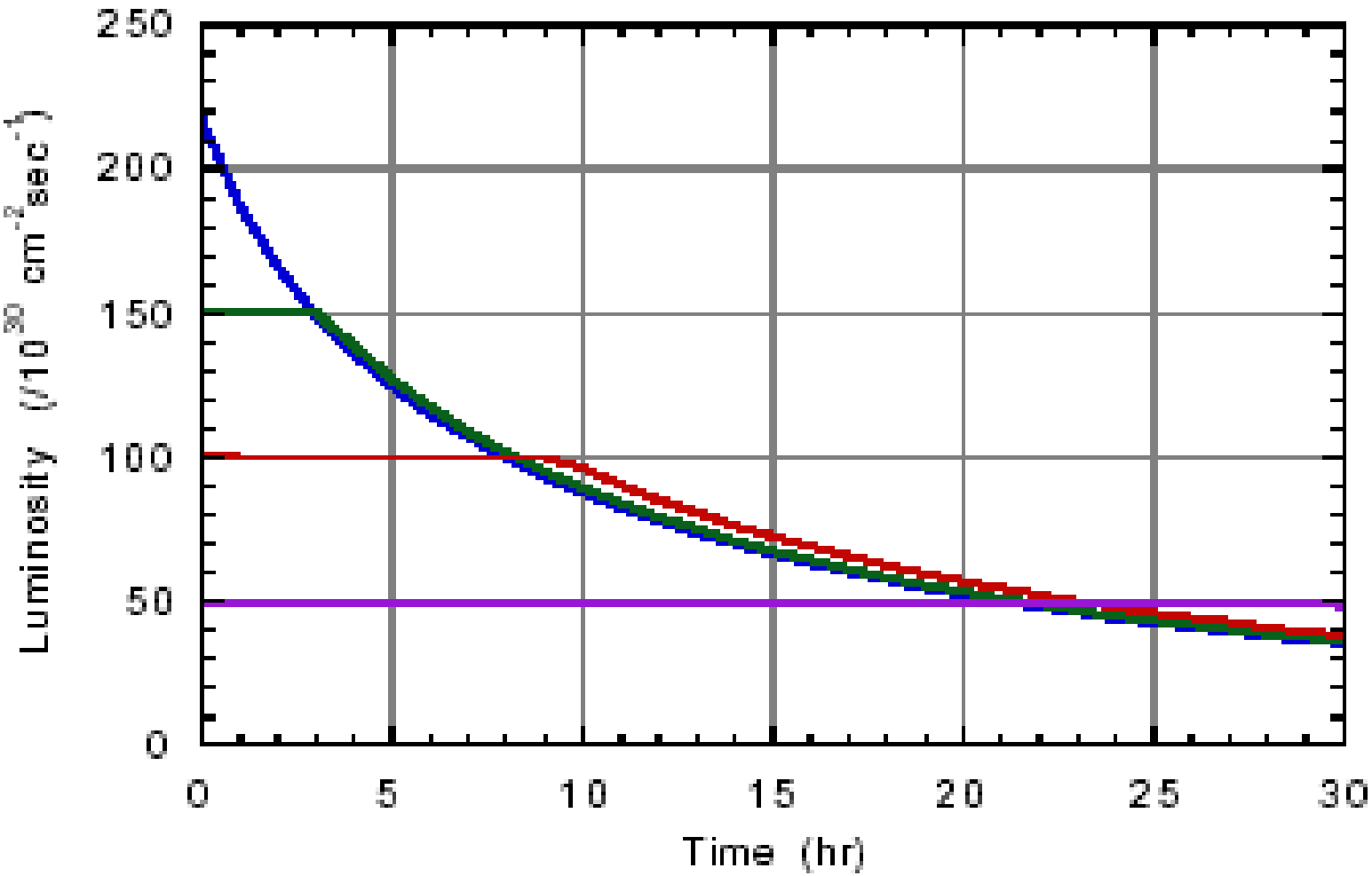
- need ~200(800) water level/roll sensors, accuracy 5 mm, 0.2 mrad
- 20 sensors 600 m system works fine in MI-8 tunnel for year (0.05 mm resol'n)
- involve TD?

BINP(Novosibirsk), V.Shiltsev, D.Plant



Luminosity Leveling

M.Martens, V.Lebedev



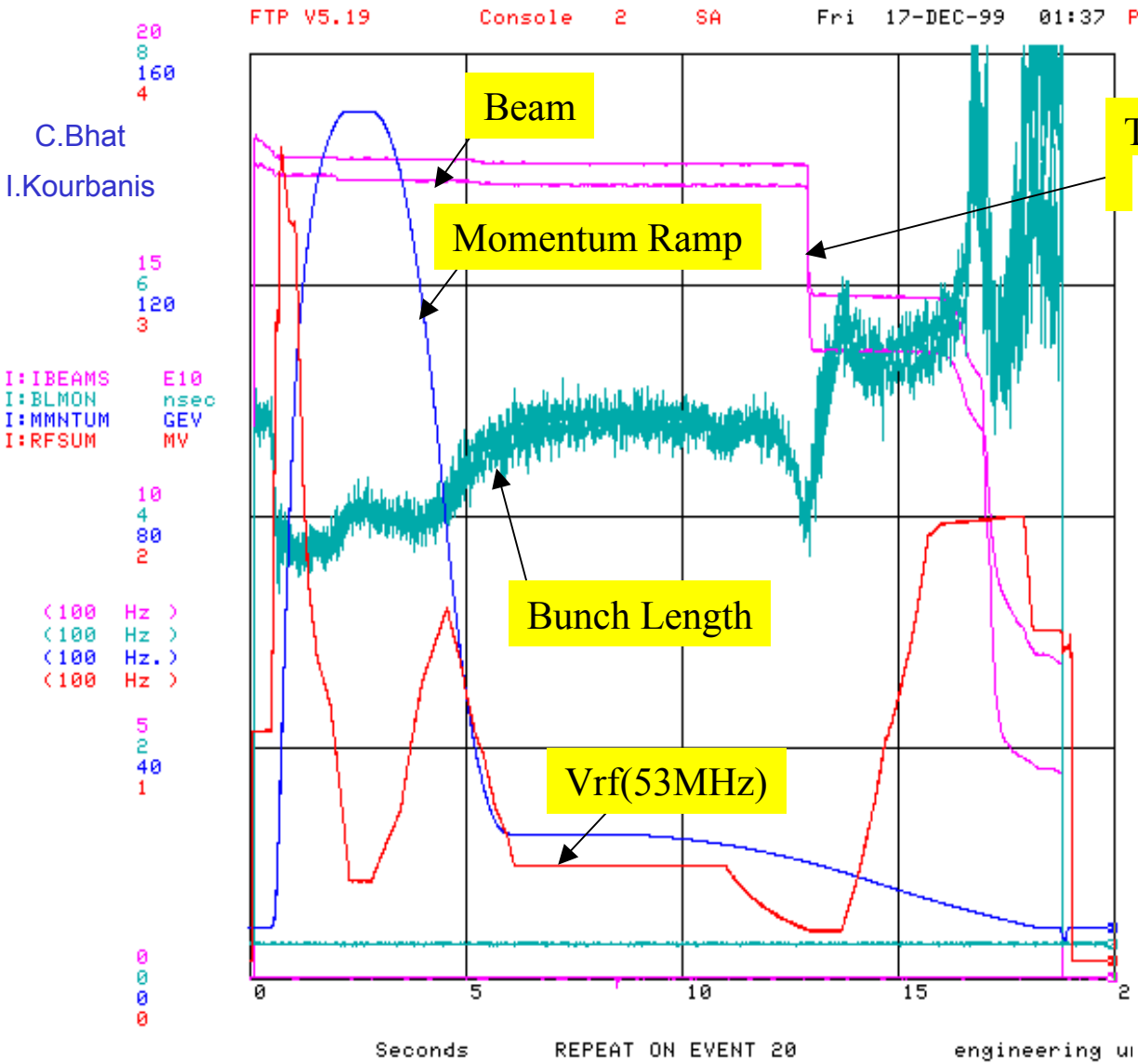
Lumi-Leveling Issues

- Needed (?) for detectors to reduce number of interactions per crossing:
  - still not certain at what level
  - not an issue now
- will impact the integrated luminosity
- There are operational concerns such as tune and orbit control over a range of β^* values and control of the beam halo rates and beam halo scraping during the leveling process.
- Plan:
  - some experiments possible

Recycling Issues in the Tevaron

- Needed (?) if recycling beneficial for integrated *L*
- proton removal:
  - dog-leg exists at E0
  - few unsuccessful attempts
- pbar deceleration:
  - tried in Run I, no problem
- pbar extraction:
  - b_2 drifts at extraction porch need to be compensated
- larger emittances wont allow 100% decel and extr
- Plan: attempt fast p-removal in FY - operational

Deceleration in MI



- p-deceleration attempted in MI
- issues: MI will accept only 3eVs from Tev
- at 25 GeV switch from 53MHz to 2.5MHz to reduce dP/P, then go thru transition→ extract to RR

Diagnostics/Hardware for Run IIu

- Need to improve existing diagnostics and hardware

  (see M.Martens talk)
- Besides that:
  - On-line chromaticity, tune, coupling, etc
  - DC beam diagnostics
  - Magnetic measurements
  - On-line survey system
  - Better/stronger dampers …

Beam Studies for Run IIU in FY03:

- If the study time wont be reduced, in the remaining 8 mos of FY03 we will have 160 shifts for beam studies
  - subtract maintenance (~60 shifts) and
    after shutdown recovery (~20 shifts)
- Out of remaining 80 we can dedicate upto 20% (1 shift a week, or total of 10-16 shifts) to Run IIU issues:
  - perfect beam models: 6
    - Beam-beam vs N_p, separation, sigma_s, cogging
    - Long. and transv. IBS vs noise in $d\epsilon/dt$
    - Multibunch instabilities (longitudinal)
  - TEL 5
  - b* variation (35cm→25cm or 35cm→100cm) 2
  - proton removal (deceleration? extraction?) 2